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United States
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Intermountain
Research Station

General Technical
Report INT-GTR-314

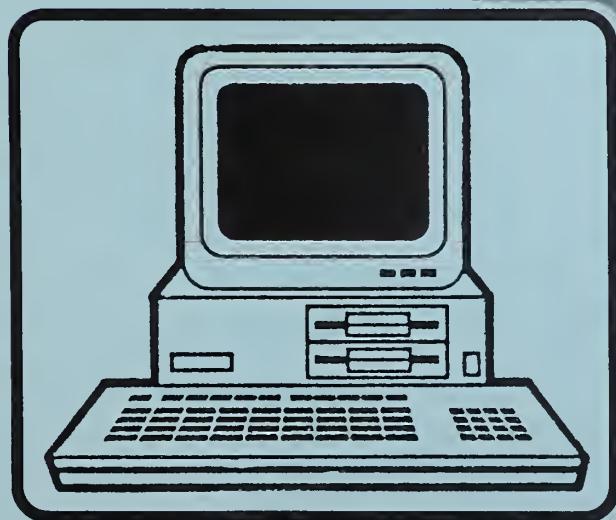
November 1994



PLUMP: a Plume Predictor and Cloud Model for Fire Manager

Don J. Latham

Accompanying diskettes
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Demonstration Center
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No. 4401



The Author

Don J. Latham received his B.A. degree in physics from Pomona College in 1960. In 1964 and 1967, he received M.S. and Ph.D. degrees in earth science, from the New Mexico Institute of Mining and Technology, specializing in atmospheric electricity and weather radar. He taught atmospheric science at the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences. In 1976, he moved to the Intermountain Research Station's Intermountain Forest Fire Laboratory in Missoula, MT, where he began studying the ignition of forest fuels by lightning discharges and the location of lightning discharges. For the past 10 years he also has been working in the field of artificial intelligence, particularly as applied to fire science and related fields. He is currently studying the interaction

between wind and fire and the generation of plumes by fires.

Research Summary

PLUMP is a general-purpose, one-dimensional plume rise model for wildfire and prescribed fire planning. It calculates the characteristics of fire plumes, including vertical velocity, water content, excess temperature, rain, and ice. The model can also be used to determine the possibility and extent of cumulus growth when estimating lightning activity. PLUMP can also be used to simulate simple convective clouds. It does not consider wind, modeling only vertical motion in a windless environment.

The cover photo shows the plume that developed above the Sandpoint fire south of Neihart, MT, on July 5, 1985. The fire had burned 1,600 acres on the Lewis and Clark National Forest when the plume rose to 30,000 feet during the afternoon. By early evening the fire had burned another 3,900 acres. Lightning had ignited the fire 3 days earlier. Bert Lindler took the photograph for the "Great Falls (MT) Tribune." He now works as a technical publications editor for the Intermountain Research Station in Ogden, UT.

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PLUMP: a Plume Predictor and Cloud Model for Fire Managers

Don J. Latham

Introduction

PLUMP is a one-dimensional, time-dependent plume model that includes parameterized cloud physics and entrainment. It generates vertical profiles of water vapor, cloud particles, rain, and ice, temperature anomaly between the plume and its surroundings, and vertical velocity of the plume from a vertical sounding of the atmosphere and varying boundary conditions. It does not consider wind, modeling only vertical motion in a windless environment. PLUMP can also simulate simple convective clouds. PLUMP should be useful for prescribed burning and for general smoke management. It can also be used to help estimate conditions that increase the likelihood for lightning, fire blowup, and downbursts.

The program (PLUMP.exe) and its antecedent files are designed to work as a stand-alone program or in conjunction with John Werth's U.S. Weather Service FireWorks program ANALYZE (NOAA, n.d.) for fire weather forecasters. PLUMP requires a computer with 640 kilobytes memory, DOS 3.1 or higher, color VGA monitor, and a math co-processor. The first part of this manual contains instructions for use of the model. Appendix A provides a brief description of the way the model works. Appendix B includes instructions for using the program with ANALYZE.

Installation

(Floppy drive B: is used for the example. Drive A: works the same way. Some knowledge of DOS is required.)

- (1) Put the files from B:\plume8 in any convenient directory.
- (2) In this directory, create a subdirectory called ARCHIVE.
- (3) Copy the sample soundings from B:\archive into this subdirectory.
- (4) Using a text editor, alter PLUME.CFG to reflect your choice of directory structure (see Configure File Structure below). If the directory in step 1 is plume8, no alteration is necessary.
- (5) PLUMP runs under Windows 3.1, occupying the entire screen (it does not run in a window). There is an icon included (PLUMP.ICO) for this use. On older machines, the program will slow down if windows 3.1 is used.

Inputs

Inputs to PLUMP consist of the contents of a configure file, data file(s), and data requested as the program progresses. The program requires other files to run (such as COURB.FON) and a utility (RESET.EXE), which we hope you will never need. These will be discussed in order.

Configure File Structure (PLUMP.CFG)

The configure file for the PLUMP program is an ASCII file structured as follows:

'THIS DIRECTORY IS...'	'C:\PLUME8'
'SOUNDINGS ARE FOUND AT...'	'C:\PLUME8\ARCHIVE'
'INPUT UNITS, (E)nglish OR (M)etric ='	'M'
'Timestep Factor = (2.0)'	2.0
'Entrainment Constant = (0.1)'	0.1
'Write to DEBUG.PL8 File = 1, ELSE 0'	0
'Autoconversion Constant (0.001)'	0.001
'Accretion Constant (0.0052)'	0.0052
'Autoconversion Threshold (0.5)'	0.5
'Viscosity Constant (0.001)'	0.001
'Entrainment Surface Radius (1000)'	1000

The records in this file consist of an explanation and a value. The explanation is read by the program and discarded; the value is incorporated for each exercise of the program. The values are, in order:

- 'THIS DIRECTORY IS...'—The directory where the program and support files reside.
- 'SOUNDINGS ARE FOUND AT...'—The directory where the vertical soundings can be found.
- 'INPUT UNITS, (E)nglish OR (M)etric ='—Choice of units for the input portion of the program, English or Metric (output plots and debug printout are always metric).
- 'Timestep Factor = (2.0)'
 - The divisor in establishing the size of the model variable timestep (the larger this number, the shorter the timesteps).
- 'Entrainment Constant = (0.1)'
 - A proportionality constant that determines the amount of external air drawn into the plume (entrainment constant).
- 'Write to DEBUG.PL8 File = 1, ELSE 0'
 - A number, 0 or 1, that outputs the first few levels to a file for inspection (the program will run considerably slower if this print command is invoked).
- 'Autoconversion Constant (0.001)', 'Accretion Constant (0.0052)', 'Autoconversion Threshold (0.5)'
 - Three numbers having to do with the rate of growth of rainfall from cloud droplets.
- 'Viscosity Constant (0.001)'
 - A number governing the amount of artificial viscosity invoked for stability.
- 'Entrainment Surface Radius (1000)'
 - The radius used for entrainment size for nonfire model runs.

The numbers in the CFG file are for program developers and for those who wish to change cloud physics parameters. Except for the directories and input mode, no changes should be necessary. The user can change the parameters. The 'correct' values are included in parentheses if the user loses the way. I urge users to leave these alone. Do not lose the single quotes on the explanation field of each record. Do return to the 'correct' values after experimenting with different values (unless, of course, the user believes different values improve the program's behavior). Do not expect miracles from adjusting these parameters.

Data File Structure

A sample file for the data structure is included (fig. 1). The archive file name must be in the form "???R????.??Z". The file must be in the

```

"UIL", "04/02/12z", 62
1006, 8.2, 7.7
1000, 8.4, 7.59
925, 3.8, 2.9
884, 1.0, .1
850, -.1, -1
825, -.1, -1
715, -8.7, -10.8
708, -9.5, -12.7
700, -11.1, -21.1
675, -11.3, -14.9
655, -13.1, -19.1
607, -16.5, -21.2
598, -15.9, -17.3
570, -19.1, -22.8
539, -19.9, -23.6
500, -23.9, -27.9
400, -36.1, -42.1
383, -38.7, -43.7
374, -39.9, -47.9
317, -47.5, 99
261, -52.1, 99
218, -54.3, 99
182, -48.9, 99
141, -55.7, 99
100, -56.7, 99
9999
1000, "104", 8.4, 7.599999
925, "744", 3.8, 2.9
850, "1426", -.1, -1
700, "2956", -11.1, -21.1
500, "5480", -23.9, -27.9
400, "7080", -36.1, -42.1

```

Figure 1—Sample input sounding file.

'SOUNDINGS ARE FOUND AT' directory specified in the file PLUME.CFG. The date, (four characters following the "R" in the file name) and the time (characters preceding the "Z"), may be arbitrary characters as they are not used by PLUMP.

The first line of the data file has a three-letter code followed by a date/time, followed by an integer which gives the station height in meters. Files archived by ANALYZE (see Appendix B) have the three-letter code corresponding to the weather station that the data comes from. Files constructed for PLUME by other means can use this space for other information. All spaces must be filled with characters to maintain the eight-character filename, and the "R" must be in fourth place. The station height is necessary and must be given in meters. If a data file is constructed from an external source such as a spreadsheet, note that the quotes must be present for the quantities on the first line.

The data are in records composed of triplets of pressure (millibars), temperature (degrees Celsius), and dew point temperature (degrees Celsius), set apart by spaces. The inputs in this file are always metric. The decimal point is necessary for the input format. The last line of the data must be a space character followed by 9999.

Note the connection between the character variables on the first line of the data file and the filename in DOS. It is not necessary for these to be the same, because PLUMP only uses the height integer. It is a good idea, though, to keep them the same.

Input Menus

The program displays two windows at its start, the header and a file selection window (fig. 2). The header window contains instructions for picking the input file from the "USE FILE" window. This window reports files from the 'SOUNDINGS ARE FOUND AT' directory (see PLUMP.CFG above) whose DOS filenames match the description given above for data files. As the header window directs, the file to be used by PLUMP is chosen with up and down keyboard arrows and the "enter" key, or by using the mouse. Only one file is picked per run of PLUMP. As indicated, the ESC key will cleanly abort the program at this point. For a first run-through, pick the file "HILR0000.00Z" at this point.

When the file has been chosen, the "CHOICES" window appears (fig. 3). The models that PLUMP can run are shown. Two input modes are available for modeling a plume generated by a fire at the ground (surface). One of these uses a loading input for the fuel; the other uses an energy release

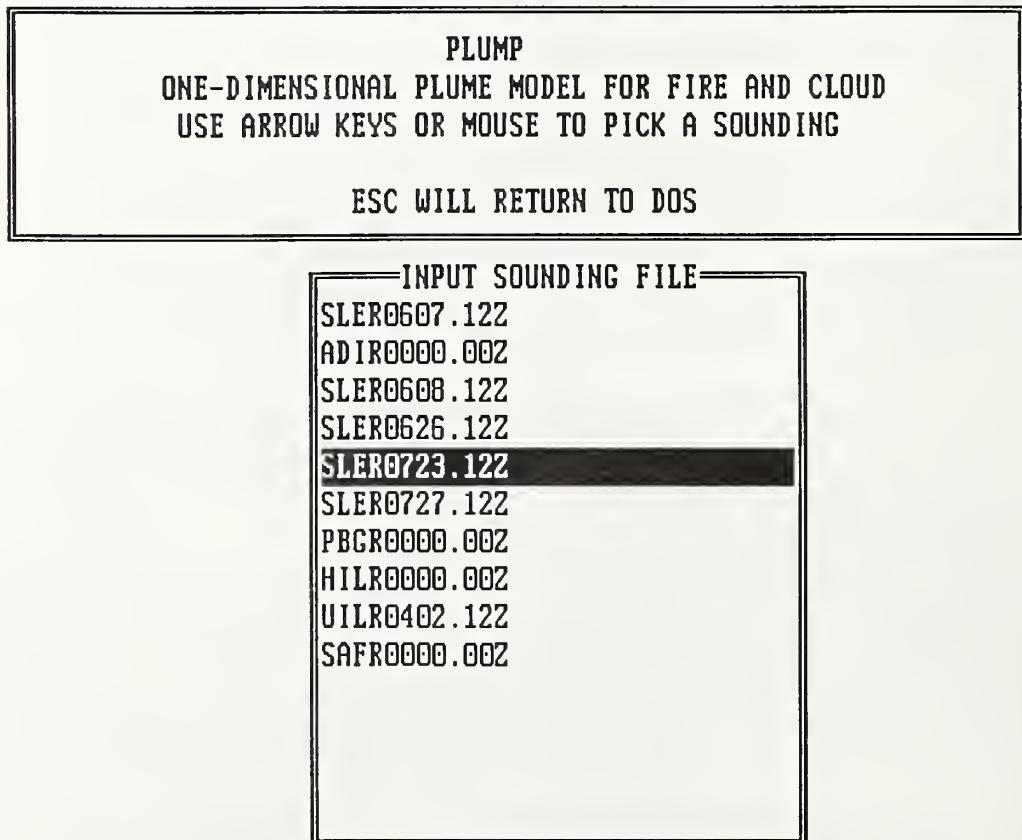


Figure 2—File choice windows.

PLUMP
CHOOSING THE DESIRED MODEL TYPE
FIRE, CLOUD, OR PARCEL LIFTING
ESC TO DIFFERENT SOUNDING

THINGS TO DO...

Plume generated by a fire, loading input

Fire (fuel mass input)
Efir (energy input)
Surface Lifting
Cloud Generation
Arbitrary Lifting

Figure 3—Model type windows.

rate. Surface lifting shows the effect of lifting a parcel from the surface. Cloud generation simulates a cumulus cloud that starts at the lifting condensation level. Arbitrary lifting simulates the effect of placing a warm parcel of air at an arbitrary level above the ground (surface level). Choosing an activity will bring up an input screen appropriate to the activity (figs. 4 to 8). Pick fire (fuel mass input) as a first run-through value. Pressing the ESC key will return the program to the File Choice screens while you are in the Choices screen.

Note: Throughout the input stage, a number must always be entered at a query. If the "enter" key is hit without a number being entered, the cursor will wind up at the left of the screen. If this happens, don't panic, just enter the appropriate number and go on. If you make a mistake, go on until reaching the reenter instruction, then reenter. No data screening is done on these inputs, so a run-time error will be displayed if input queries are answered with anything except numbers. Just restart the program if this happens.

Input data are taken in order. Each query appears after the preceding one has been satisfied. The SURFACE HEIGHT may be any desired height above the sounding surface. If a number smaller than the sounding surface is entered, the surface will default to the sounding surface. This feature enables a sounding from a lower elevation to be used for a fire at a higher elevation. The result isn't absolutely correct, of course, but that is the best that can be done for now. Entering a "0" will, as promised, set the surface at the first sounding level (first run-through, 0).

PLUMP
CHOOSING INPUT PARAMETERS
FOR THE DESIRED MODEL
INPUTS IN METRIC UNITS

FIRE BOUNDARY CONDITION, LOADING INPUT
SURFACE HEIGHT (0 FOR DEFAULT), M = ?0
DELTA Z (0 FOR DEFAULT), M = ?0
DURATION OF BURN, MINUTES = ? 30
AREA OF BURN, HA = ? 400
BURNED LOADING, KG/M² = ? 12
FUEL MOISTURE, % = ? 20
TOTAL MODELLED TIME, MIN. =?50

TO RE-ENTER DATA, HIT ESCAPE
TO GET ON WITH IT, ANY OTHER KEY

Figure 4—Fire model choice input windows, loading input.

PLUMP
CHOOSING INPUT PARAMETERS
FOR THE DESIRED MODEL
INPUTS IN METRIC UNITS

FIRE BOUNDARY CONDITION, ENERGY INPUT
SURFACE HEIGHT (0 FOR DEFAULT), M = ?0
DELTA Z (0 FOR DEFAULT), M = ?0
DURATION OF BURN, MINUTES = ? 30
AREA OF BURN, HA = ? 400
ENERGY RELEASE RATE (FLAMING), WATT/M² = ? 12000
FUEL MOISTURE, % = ? 12
TOTAL MODELLED TIME, MIN. =?50

TO RE-ENTER DATA, HIT ESCAPE
TO GET ON WITH IT, ANY OTHER KEY

Figure 5—Fire model choice input windows, energy input.

PLUMP
CHOOSING INPUT PARAMETERS
FOR THE DESIRED MODEL
INPUTS IN METRIC UNITS

LIFT A PARCEL FROM THE SURFACE
SURFACE HEIGHT (0 FOR DEFAULT), M = ?0
DELTA Z (0 FOR DEFAULT), M = ?0
TEMPERATURE ANOMALY, DEGREES C = ?1
TOTAL MODELLED TIME, MIN. =?40

TO RE-ENTER DATA, HIT ESCAPE
TO GET ON WITH IT, ANY OTHER KEY

PLUMP
CHOOSING INPUT PARAMETERS
FOR THE DESIRED MODEL
INPUTS IN METRIC UNITS

CREATE A CLOUD AT THE LCL
SURFACE HEIGHT (0 FOR DEFAULT), M = ?0
DELTA Z (0 FOR DEFAULT), M = ?0
TEMPERATURE ANOMALY, DEGREES C = ?1
TOTAL MODELLED TIME, MIN. =?40

TO RE-ENTER DATA, HIT ESCAPE
TO GET ON WITH IT, ANY OTHER KEY

Figure 6—Surface lifting model input windows.

PLUMP
CHOOSING INPUT PARAMETERS
FOR THE DESIRED MODEL
INPUTS IN METRIC UNITS

LIFT A PARCEL FROM A SPECIFIED HEIGHT
SURFACE HEIGHT (0 FOR DEFAULT), M = ?0
DELTA Z (0 FOR DEFAULT), M = ?0
TEMPERATURE ANOMALY, DEGREES C = ?1
HEIGHT OF ANOMALY, M = ?2000
TOTAL MODELLED TIME, MIN. =?40

TO RE-ENTER DATA, HIT ESCAPE
TO GET ON WITH IT, ANY OTHER KEY

Figure 8—Arbitrary lifting model input windows.

Delta Z, the grid spacing, should be left at the 100-meter default unless a look closer to the surface is desired. As Delta Z is decreased, the running time of the program increases. Since the timestep factor of two is already a minimum, the program will not run faster. In addition, the estimation of the sounding at small grid spacings is poor because detailed structure cannot be added to the data (first run-through, 0).

The next inputs in the fire activity are values for variables connected to the fire for which the plume behavior is sought. In order, they are:

DURATION OF BURN—The period of time in minutes that fire activity is expected to last (first run-through, 30).

AREA OF BURN—The planned ignition area (first run-through, 400) in hectares, or acres.

BURNED LOADING—The weight of fuel expected to be consumed per unit area, in kilograms/square meter or tons/acre. This value is an estimate based on experience or on other programs. If you need to guess, use one-half of the total loading. The energy of this amount of fuel is assumed to be generated at a uniform rate during the period given in "duration of burn" above (first run-through, 6).

FUEL MOISTURE—A representative fuel moisture, in percent, for the entire fuel complex. The 10-hour class fuel moisture seems to be best. This amount of moisture is added to the moisture of combustion and included in the parcel of hot air at the boundary (first run-through, 12).

TOTAL MODELED TIME—The duration of the model run time in minutes. This time will default to the burn duration if it is input as less. You can observe behavior of the plume after burning has ceased (first run-through, 40).

Finally, you are given a choice to reenter data. At this point, an "ESC" key will send the program back to the beginning of the data input screen. Note that the program may be cleanly aborted by another "ESC" at the choosing a model screen, and another "ESC" at the Sounding File screen (first run-through, hit any key and have a look at a typical output).

The input screens for the other activities (figs. 5 to 8) look much the same as the example just run. The only new input requested is TEMPERATURE ANOMALY. The user is asked for a value of temperature excess in degrees Celsius or Fahrenheit to be applied to the initial parcel of air for the model run. Unless there is some reason otherwise, a value of 1 degree Celsius or 3 degrees Fahrenheit will do nicely. Similar inputs are requested for the cloud and arbitrary activities.

Outputs

Typical outputs are shown in figures 9 and 10. These are "snapshots" of the screen output, which is dynamic. Since the manual is black and white, a much better appreciation for the outputs can be had by simply running the program with a color monitor. A brief description of the output traces and information follows.

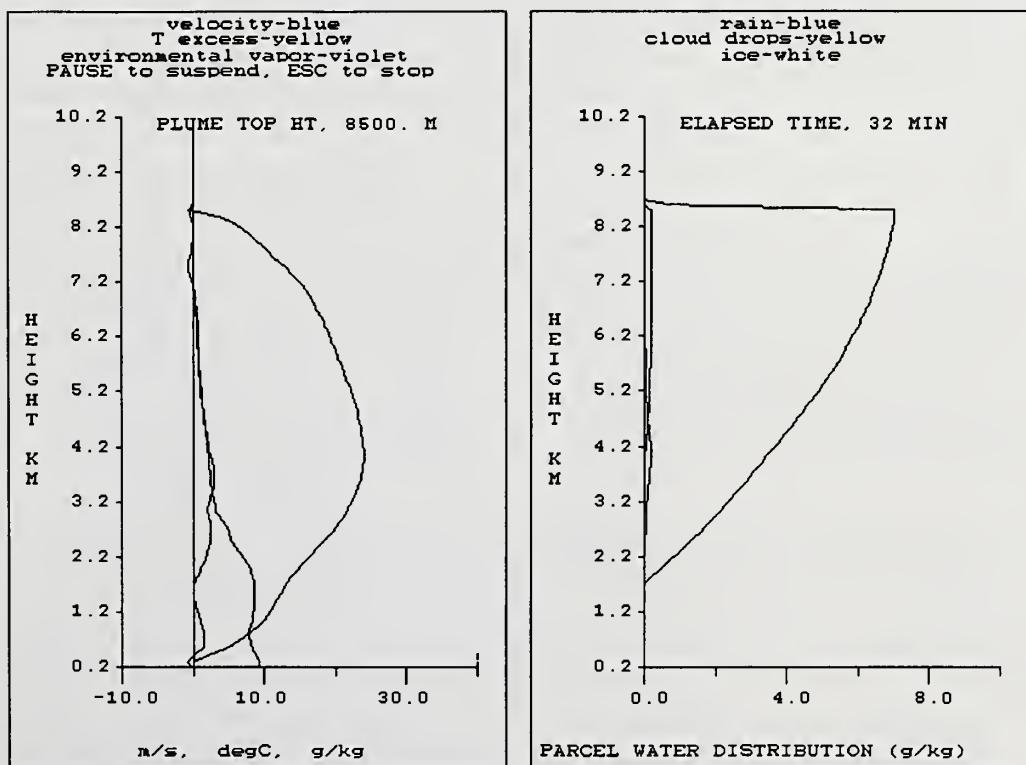


Figure 9—Cloud choice output.

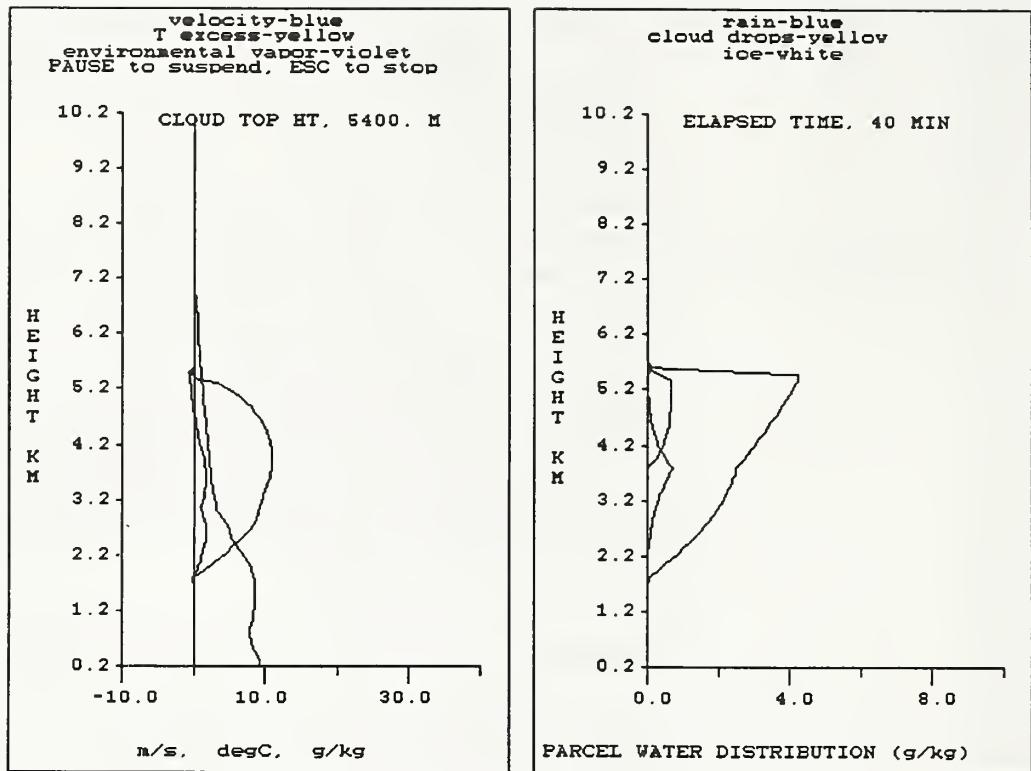


Figure 10—Fire choice output.

Output information is given in two windows containing axes and the descriptors for the traces. The left-hand graph displays the upward velocity of the parcel in meters/second, the temperature excess of the parcel over the environment at the same level in degrees Celsius, and the environmental liquid water content (vapor) in grams/kilogram of dry air. All horizontal scales have the same numerical values. The height scale is determined by Delta Z as chosen in the choices window, first step. Also displayed permanently on the left-hand graph are pause and escape instructions. Pressing the appropriate keys will cause the actions (the pause key is near scroll lock and print screen on the keyboard; now you know what it's for). Pressing any key will resume the action after a pause. Occasionally, the pause will stop the program during display refresh and some traces will appear to have vanished. Just resume and pause again until a satisfactory picture appears. Hitting the ESC key twice will cause a clean exit from the program while the output screen is running.

The remaining information on the left-hand graph is the plume top height as calculated in the program. Occasionally, this value will be unreliable. A look at the velocity trace will quickly show whether this value is suitable, as the upward velocity will be zero at the top of the plume or cloud.

The right-hand graph is a summary of the disposition of water within the plume. Cloud droplets are the product of condensation. Rain is the amount of water in the form of liquid hydrometeors, and is extracted from cloud droplets by accretion and collection. Ice is ice in platelet form, but does not include hail, which is included in rain. Also shown in this window is the

elapsed time of the model as it runs. Crude estimates of plume rise speed can be obtained from this value. Again, running the model will provide a much better look at the nature of the outputs.

Uses

As mentioned in the introduction, PLUMP can be used for tasks other than estimating fire plumes. Lightning activity levels can be estimated by growing a cumulus cloud and observing the depth of convection. Convective depth has been related to convection (Fuquay 1980) as follows:

Lightning activity level	Echo height (kilometers)
2	<8.5
3	7.0-9.7
4	9.1-11.0
5	>11.0

Plumes that are tall and isolated will sometimes issue smoke from their side in a streamer. This possibility and the level of the streamer can be estimated by looking at the fire cloud overshoot. To do so, first run PLUMP as a cumulus cloud model. Note the height estimate for normal convection. Then run PLUMP for the planned fire. The difference between the heights indicates the overshoot due to the fire. The cloud top predicted without the fire is an estimate of where the smoke streamer might issue.

The possibility of downbursts intensified by fire can also be estimated using this procedure. If the lower layer is dry with moist air aloft, and if the overshoot is large, there is a good possibility of downburst activity. This procedure provides only a very rough guideline at this point; it requires further investigation to sharpen it up.

Example Soundings

Several input soundings files are provided. Briefly, they are:

HILR0000.00Z—A sounding taken during summer in Ontario, Canada.

The input values given above as first run-through correspond to the actual values of the prescribed burn conducted then.

SLER... and UIL...—Summer soundings from the Western United States (Salem, OR, and Quillayute, WA) that show inversions typical of the summer in that region.

ADIR...—A dry adiabat.

SAFR...—A summertime sounding from Kenya. Note the behavior of the plumes and clouds with the big inversion shown by the environmental vapor curve in the output.

PBGR...—A summertime sounding from Phillipsburg, MT. Any fire or lifting input will grow a huge plume.

An Important Note: If the program terminates with an error message, the program RESET.EXE should be run immediately to restore the proper screen function. This shouldn't happen of course, but Murphy is always

with us. Please send reports of bugs, comments, and other communications regarding this model to:

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READING LIST AND LITERATURE CITED

Note: The Bibliography is meant to be a reading list as well as citations.

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Appendix A: The Model's Construction

This appendix is a brief description of the inner workings of the PLUMP model. It is not intended to be a detailed exposition of the program code.

The program contains six main elements: input, equally-spaced sounding generation, advection, water balance, boundary conditions, and output.

Input

There is nothing special about this code. Crude windowing is used to separate functions for clarity and ease of use. A configuration file helps resolve the torment of keeping file directory paths straight or at least easily modifiable. Paths to exit while inputting have been included. Trying to get a simple “enter” to do a default is excruciating in Fortran, so a number input is necessary at every query. Fortunately, the numbers can be entered free-form. File structure for soundings was governed by the FireWorks ANALYZE archive program, but simple ways to generate this structure can be devised by the user if necessary. This part of the program, as well as the output section, could be changed to suit Windows or some other environment without too much difficulty.

Advection

The advection scheme used in PLUMP is a scheme that is forward-differencing in space and forward in time. Although somewhat old-fashioned, it has the virtue of simplicity (Pielke 1984). For stability, some artificial viscosity has been included (Peyret and Taylor 1983). No internal structure connects this viscous damping in any formal way to eddy viscosity concepts, so the viscosity constant in the configuration file is just a number that alters the effect damping has on the model.

Because the model generated growing instabilities as the velocity passed through zero, and at places like the bottom of clouds and the nonfire lower boundary, a very small random number replaces the vertical velocity value at every space step if the value is near zero. This small dither swamps the growth of numerically caused instabilities nicely without doing violence to the representation of the physics. This is, by the way, the first model the author has seen with this dither. Maybe a first?

Entrainment of environmental air is taken to be proportional to the vertical velocity in the parcel or plume. The radius of the plume is taken to be constant for all but the fire choice. For this choice, the plume grows according to standard elementary theory (Briggs 1969; Turner 1973).

Water Balance

Simple parameterization is used here as well. Parameterizations were taken from Kessler (1969) and Pruppacher and Klett (1978). These were applied in much the same way as in Weinstein (1970) and Ogura and Takahashi (1971). In these parameterizations, cloud water is condensed from vapor after vapor concentration reaches saturation in the plume. Rain then forms from the cloud droplets by accretion and autoconversion. As the plume grows higher, ice can form both from rain and from cloud

droplets. Evaporation and sublimation can return water and ice to vapor, and ice can also melt. Median dropsize and other parameterization is used to represent the speed at which water drops and ice fall.

Boundaries

The upper boundary for the model is placed at a great height by appending the last few points (tens of millibars) of the summer ICAO (International Civil Aviation Organization) standard atmosphere to the input raw sounding. The top boundary is taken to be leaky, with values at the last gridpoint equal to the one below. There is, then, no "lid" on this model.

There are two lower boundary conditions; one for fire and one for the rest. All but fire have a sink for rain (and ice). The values for other variables at the lower boundary are set to the environmental values and held there. The velocity is set to zero. With the addition of the dither mentioned above, this has proved satisfactory. In the case of surface choice for parcel lifting, the temperature anomaly is actually started at the first level above the surface level.

The fire boundary condition is based on a virtual point source of buoyancy placed below the ground. The buoyancy generated by this source is calculated from the energy as given by the weight of fuel per unit area, the duration of the burn, and the area of the fire. This buoyancy flux is used to calculate the velocity and the temperature that this kind of plume would have at the level of the surface. The water vapor generated by the fire per unit area for the timestep is added to the environmental vapor; the result makes up the boundary condition on the water vapor. This approach has proven satisfactory for the kind of one-dimensional calculations in the model. It is a parameterization for the near-surface inflow that a higher dimension model would have. Because of this approach, fire plumes sometimes seem weaker than plumes generated by the Surface choice.

Output

The output section uses a windowing and graphics package. There is an option to dump the first few levels of the output to a file once a model minute. This is a debugging aid, and although interesting, is too raw to be of much operational use.

Appendix B: Using PLUMP With the FireWorks Program ANALYZE

FireWorks is a program used by the U.S. Weather Service for vertical analysis. This program uses data from standard Weather Service soundings in RAOB sounding format, and will archive the soundings in a form that PLUMP reads. To implement PLUMP with ANALYZE:

To install in FireWorks:

- (1)—Make a directory c:\fwxpgms\analyze\plume8.
- (2)—Put the files from this disk, B:\plume8, into the new directory.
- (3)—Copy the sample data files from B:\archive into C:\fwxpgms\analyze\archive.
- (4)—Alter the PLUMP.CFG file to read:
‘THIS DIRECTORY IS...’
‘C:\FWXPGMS\ANALYZE\PLUME8’
‘SOUNDINGS ARE FOUND AT...’
‘C:\FWXPGMS\ANALYZE\ARCHIVE’.
- (5)—Run PLUMP from c:\fwxpgms\analyze\plume8.
- (6)—If all has gone well, you should see a window with ANALYZE archive files in it. If not, make sure that C:\fwxpgms\analyze\archive is there and has files in it. Files from ANALYZE have more data after the 9999 record; these are not read by PLUMP. Files constructed according to the rules in this document will not be read by ANALYZE, but PLUMP will read archive files generated by ANALYZE.

Latham, Don J. 1994. PLUMP: a plume predictor and cloud model for fire managers. Gen. Tech. Rep. INT-GTR-314. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 15 p.

PLUMP is a general-purpose, one-dimensional plume rise model for wildfire and prescribed fire planning. It calculates the characteristics of fire plumes, including vertical velocity, water content, excess temperature, rain, and ice. The model can also be used to determine the possibility and extent of cumulus growth when estimating lightning activity.

Keywords: smoke plumes, plume rise, clouds, smoke management, fire weather, computer models, smoke plume models

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PLUMP
One-Dimensional
Plume/Cloud Model
Version 1.1

Don J. Latham
RWU INT-4401

Science Sciences Laboratory
Mountain Research Station

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INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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